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COVER SHEET FOR TECHNICAL MEMORANDUM

TITLE- Countdown Hold Statistics

TM-68-2014-1

DATE- January 8, 1968

FILING CASE NO(S)- 310

AUTHOR(S)- W. B. Gevarter

FILING SUBJECT(S)- Countdown, Reliability, Prelaunch
(ASSIGNED BY AUTHOR(S)- W. B. Gevarter

N79-72063

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(NASA-CR-93419) COUNTDOWN HOLD STATISTICS
(Bellcomm, Inc.) 47 p

ABSTRACT

This memorandum presents countdown hold statistics for the Saturn I and IB, Atlas SLV-3, Gemini, and Thor-Delta launch vehicles. These statistics have been gathered and reduced to provide background material for the consideration of "Launch-on-Time Strategies," and the effects of built-in holds and varying launch window sizes on launch availability.*

It was found that the rate of occurrence of unscheduled holds increases as T - 0 is approached. The expected number of holds (including scrubs) in the last ten minutes of countdown ranged from 0.6 for Gemini to 1.0 for Atlas. The median individual hold length during the last ten minutes, ranged from seven minutes for Gemini to twenty-seven minutes for the Saturn I and IB's.

Several launch attempts were required for some vehicles. Considering the average of the vehicle types, 75% of the launch attempts actually launched. Of those that launched, 35% launched on time (i.e. had no unscheduled holds). With scheduled holds (of sufficient duration) at ten minutes before ignition, 63% of the vehicles actually launched could have been launched on time.

*Launch availability is defined as the probability of being ready to accomplish the mission during the assigned launch window.

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The principal causes of countdown discrepancies were:

	% of Holds	% of Scrubs
Ground Support Equipment	18%	23%
Launch Vehicle Propulsion	17%	23%
Guidance and Control	16%	31%
Range	11%	-

Except for Atlas, for which no detailed data was available, there was no direct indication that any discrepancies can be directly attributed to holds.

Projecting this data, it appears that for a launch vehicle such as Saturn V, which has a very limited hold capability at countdown times later than 20 minutes, that a combination of built-in holds (the last as late in the countdown as possible) combined with several launch window panes (to allow for recycling) would be highly desirable for increasing launch availability. Saturn V recycles to a countdown time of 20 minutes before ignition, if a discrepancy occurs in the last 20 minutes. Considering the median hold times found for Saturn I and IB, it appears that two launch window panes approximately one hour apart would be a reasonable compromise between (1) increasing launch availability and (2) minimizing range, trajectory, and software complexity, and payload loss.

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BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Countdown Hold Statistics
Case 310

DATE: January 8, 1968

FROM: W. B. Gevarter

TECHNICAL MEMORANDUM

I. INTRODUCTION

This memorandum presents countdown hold statistics for several launch vehicles. These statistics have been gathered and reduced to provide background material for the consideration of "Launch-on-Time Strategies", and the effects of built-in holds and varying launch window sizes on launch availability.*

II. VEHICLES CONSIDERED

Countdown data was obtained from Reference (1) and is summarized in the form of input matrices in Tables 1a through 1d for the following launch vehicles:

Saturn I and IB

Titan II Gemini Launch Vehicle

Atlas SLV-3 7000 Series (Air Force Standard Launch Vehicle)

Thor-Delta Vehicles (1-21)

These vehicles, all launched from the Cape Kennedy area, could be considered to be representative of countdown holds associated with space launch vehicles, and range and ground support systems.

III. THE NATURE OF A COUNTDOWN

The countdown is a step-by-step process performed in accordance with a preplanned time schedule whose performance goal is to launch the space vehicle within a specified launch window without any undiscovered critical malfunctions. The time schedule is measured in terms of T-time, that is, T minus the time prior to initiation of space vehicle liftoff. The countdown serves not only to prepare the space vehicle for launch, but to syncronize launch preparations with supporting operations such as tracking, communications and range safety. It is also designed to assure maximum safety of ground and flight crews while the launch preparations are in progress.

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*Launch availability is defined as the probability of being ready to accomplish the mission during the assigned launch window.

The duration of the countdown is determined by the time required to complete the "critical-path" of operations. Critical-path can be defined as that particular sequence of operations which has the greatest negative or least positive activity slack. Only actions in the critical-path are considered critical to the progress of the countdown. If a discrepancy occurs in one of the operations proceeding in parallel to the critical-path, the countdown will normally proceed while the discrepancy is being corrected. A hold in the countdown will be called when an anomaly occurs in one of the critical-path operations. Problems occurring in the parallel operations only cause a hold when the time to effect repairs becomes so long as to impact the critical-path of operations (in effect, the parallel operation becomes part of the critical-path).

During a hold in the countdown, further problems may occur in the area of those parallel operations which are continuing, or due to failures (human and equipment) occurring in equipment on standby operations. In all probability, these discrepancies would have occurred anyway and are not directly related to the hold. Most anomalies, however, seem more likely to occur during change-of-state transients occurring during an event rather than during standby operations. The effect of a hold on reducing launch availability by inducing discrepancies in other events, is probably much less than that which might be anticipated from examining <u>only</u> the rate-of-occurrence of holds during countdown.

The countdown-hold data contained in Reference 1 does not give the T-time when the anomaly causing the hold first occurred (it just gives the T-time the associated hold was called). Other information such as the relationship between one hold and another, whether the discrepancy occurred during a transient in the countdown or during a steady-state condition, or information on secondary activity occurring during the hold, also is not contained in Reference 1. Nevertheless, sufficient information is available to roughly compute the statistics of when the holds do occur, how often they occur, the length of time necessary to correct or compensate for the malfunction, and how often and when scrubs are called. These and similar statistics which are useful in planning countdown strategy and in giving gross predictions of launch availability, have been computed and are presented in this memorandum.*

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*Unfortunately, the data is probably too heterogeneous, biased, and uncontrolled to warrant much more than a description of broad operational characteristics and trends. That is to say, the associated confidence limits for the resulting statistical curves can be expected to be large.

IV. APPROACH

Because there are so many statistical questions that can be asked from a given set of data, and such a large quantity of data, it was decided to prepare a simple computer program to logically extract the desired information from the data matrices, and compute the associated cumulative probabilities. This was done by Mrs. Sheryl Watson. The curves in this memorandum are based upon this program. Following the suggestion of Mr. A. P. Boysen, Jr., cumulative distribution plots have been chosen for statistical presentation of the basic data, because all significant statistical information on the point in question can be directly discerned from these plots, or can be derived from them.

V. TIMES IN COUNTDOWN AT WHICH UNSCHEDULED HOLDS OCCUR

A. Time of Holds

Figure 1 is a plot of the distribution of the times in the countdown* at which holds occur.

B. Holds Expected

Figure 2 presents the expected number of remaining holds as a function of countdown time.

C. Hold Rates

Figure 3 presents hold rates.

D. Time of Last Hold

Figure 4 gives the cumulative distribution of the times of the last hold in a launch countdown.

E. Time of Scrub

Figure 5 presents the cumulative distribution for the times of scrubs.

VI. LENGTHS OF HOLDS (Time to Correct Discrepancies)

A. Total Hold Length

Figure 6 presents the cumulative distribution plots for the total hold lengths.

B. Lengths of Individual Holds

Figure 7 presents cumulative distribution plots for lengths of holds (scrubs are considered to be holds of large lengths) for various intervals in the countdown.

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*For the remainder of this memo, T will designate time in countdown in minutes before launch.

C. Expected Value of Remaining Unschedule Hold Time

Figure 8 presents the expected (average) value of the remaining unscheduled hold time for Saturn I and IB, the only vehicles without scrubs in the latter portion of the countdown.

VII. HOLD REASONS

Table II orders the hold data of Table I by causes. Table III relates these reasons for holds to frequency of occurrence. Classification of holds by causes is somewhat arbitrary, the category in which a hold is placed being dependent upon the choice of classification. In addition, the basic data is somewhat incomplete, and a single failure may involve several areas.

VIII. NUMBER OF HOLDS

Table IVA relates the number of unscheduled holds to the vehicle number in the series. Tables IVB and IVC presents probabilities for the number of holds per launch and scrub.

IX. LAUNCH SUCCESS

Launch Success data is summarized in Tables V and VI.

X. CONCLUSIONS

A. Time of Holds and Hold Rates:

(1) Distribution of the times of holds

Because the curves of Figure 1 are roughly straight lines on semi-log paper, a reasonable approximation to the distribution of the times of occurrence of unscheduled holds is of the form:

$$P(\text{Time of Hold} \leq T) = a + c \log (T+b)^*$$

where: T = Countdown time ~ minutes before launch.

From the curves we observe that 50% of the holds occurred at a time less than 25 minutes before launch for Saturn, while for the much simpler Thor-Delta vehicle the time is 2.5 minutes.

(2) Number of Holds Expected in Remaining Countdown

A related, but much more useful plot is the expected number of holds ($\overline{n}$) during the remaining countdown as

*Where appropriate, approximate formulas will be presented which can be useful in attempting to macromodel a countdown.

a function of T. This is obtained by integrating the ensemble average of all unscheduled holds during both launches and scrubs. Thus:

$$\bar{n}(T) = \sum_{\substack{\text{for all } \tau \leq T \\ \text{such that } n(\tau) > 0}} \frac{n(\tau)}{N(\tau)} \qquad (2)$$

where $n(\tau)$ = number of holds occurring, for all launch attempts, at countdown time, τ.

$N(\tau)$ = number of launch attempts operative at time τ.

The curves for the expected number of holds remaining at time T are given in Figs. 2a-2d. It is interesting to note from these curves that for Saturn at 19 minutes before launch, and for Atlas at 10 minutes we still expect one hold. By contrast, Thor has less than 1 unscheduled hold expected for the entire countdown while Gemini has a expected value of 1.0 hold at the start of the countdown.

The following formulas were found to give reasonable approximations to this data:

$$\begin{aligned}
&\text{Saturn: } \bar{n} = 0 + 1.1\,[\log\,(T+2.2) - \log 2.2] \quad \text{(base 10)} \\
&\text{Atlas: } \bar{n} = 0 + 1.2\,[\log\,(T+1.6) - \log 1.6] \\
&\text{Gemini: } \bar{n} = .14 + .30\,[\log\,(T+.31) - \log .31] \\
&\text{Thor: } \bar{n} = .09 + .53\,[\log\,(T+.82) - \log .82]
\end{aligned} \qquad (3)$$

(3) <u>Holds Rates</u>: (Holds/min)/vehicle

The rate of occurrence of holds can be obtained by differentiating Equations (3) to obtain:

$$\text{Saturn } \frac{d\bar{n}}{dT} = \frac{.21}{\frac{T}{2.2} + 1} \qquad (4)$$

$$\text{Atlas:} \quad \frac{d\bar{n}}{dT} = \frac{.33}{\frac{T}{1.6} + 1}$$

$$\text{Gemini:} \quad \frac{d\bar{n}}{dT} = \frac{.42}{\frac{T}{.31} + 1} + .14\delta(T) \qquad (4)$$

$$\text{Thor:} \quad \frac{d\bar{n}}{dT} = \frac{.28}{\frac{T}{.82} + 1} + .09\delta(T)$$

These rates are presented in Fig. 3. Observe that all the vehicles have terminal hold rates in the order of .3 holds per minute of countdown, plus delta functions associated with holds (or scrubs) occurring at ignition.

The rates obtained from these formulas are in good agreement with rates obtained by considering the number of holds present in a given time interval.

The hold rates shown are the average which occur as the countdown proceeds and are not to be taken as the rates of occurrence of discrepancies during holds. This will be discussed in more detail in Section X-M.

B. Time of Last Unscheduled Hold:

As the curves of Figure 4 are nearly straight lines when plotted on log-probability paper, the time of the last unscheduled hold appears to be roughly characterized by a log-normal distribution. From the curves, 19% of the Geminis, 36% of the Thor-Deltas, 48% of the Saturns and 62% of the Atlas launches had holds at countdown times equal to or less than 10 minutes before launch. This is not intended to indicate that all these holds were due to discrepancies that first occurred at these times, but rather that holds for discrepancies were called at these times. As indicated earlier, insufficient information is available to ascertain the original time of occurrence of these discrepancies.

C. Time of Scrub:

Because the curves of Fig. 5 are roughly straight lines on semilog paper, the time of scrub curves can be approximately written in the form:

$$P\ (\text{Time of Scrub} \le T) = a + c \log (T + b) \qquad (5)$$

From Fig. 5, we observe that the scrubs for Saturn occur much earlier in the countdown than for Gemini. However there is insufficient data here to be much more specific than this.

D. Total Hold Time:

The curves of Figure 6 (appearing roughly as straight lines on probability paper) indicate that the total hold times for launches are approximated normally distributed. From the curves roughly 5% of the Atlases, 15% of the Saturns, 52% of the Thors and 58% of Gemini Launches can be expected to be on time. These figures are summarized in Table V.

E. Lengths of Holds:

From Figures 7 we observe that an approximation for the cumulative distributions of the length of holds is of the form:

$$P\ (\text{Hold Length} \leq H) = \frac{a + bH}{1 + \left(\frac{H}{H_1}\right)^2} + \frac{e + dH}{1 + \left(\frac{H_1}{H}\right)^2} \qquad (6)$$

Where H_1 may be interpreted as a break point in the hold lengths, which separates the longer holds for action items and repairs from the shorter holds for checks or decision making.

We also observe that the longer holds occur earlier in the countdown, while just before launch we have a larger number of short holds for the purpose of checks and calibrations.

F. Expected Value of Remaining Unscheduled Hold Time:

From Fig. 3 we observe that the rate of occurences of unscheduled holds increases as we approach launch. However, from Fig. 7 we see that the holds lengths become somewhat smaller during the terminal portions of the countdown. As the two phenomena are opposing, it is not immediately clear how the remaining hold time behaves as a function of countdown time. To obtain a better picture of this, the expected (average) value of the remaining unscheduled hold time for the Saturn vehicles is presented in Fig. 8. Saturn was chosen for presentation, as it is the only vehicle not having scrubs (holds of very large duration) late in the countdown. It is observed that for Saturn, the hold rate dominates over the hold lengths in determining the form of the curve.

G. Hold Reasons:

From Table III, the principle reasons for unscheduled holds are:

Ground Support Equipment - averaging 18.1% of the holds (Propellent Loading 7.0%, General 11.1%)

Launch Vehicle Propulsion System - averaging 16.6% of the holds.

Guidance and Control - averaging 16.2% of the holds

Range - averaging 11.1% of the holds

H. Number of Holds:

The average number of holds per launch (referring to Table IVA) ranged from 0.4 to 4 depending on the launch vehicle. The average of the vehicle-averages is 1.8. The average for all the launches considered is 1.1.

I. Launch Success:

Referring to Table V, we observe the following percentages (obtained by averaging the results for the four vehicles):

Attempts actually launched: 75%

Launches launched on time.* 35%

5% of vehicles brought to launch scrubbed at launch.

J. Effect of Built-in Holds:

As indicated in Table V, if there were sufficient distributed holds of long enough duration during countdown, the last occurring at T = 10 minutes, the % of launches launched on

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*Atlas and Thor did have distributed built-in (scheduled) holds (not shown in the basic data) for catch up purposes in their countdown. However, for the purposes of this memo, only launches without unscheduled holds will be considered to have launched on time.

time could be raised from 35% to 63%.* With a built-in hold at T = 1 minute, the launches launched on time could be raised to 91%. This assumes no discrepancies (having holds exceeding the end of the hold time) occurred during the last hold. As 5% of the vehicles brought to launch scrubbed at launch, this indicates that the best that could be done with built-in holds in achieving launch-on-time is in the order of 95% of the launch attempts.

K. Number of Launch Attempts Required for Launch:

Table VI presents statistics on the number of launch attempts required for launch. It indicates that (taking the average for the vehicle types) 73% of the vehicles launched on the first attempt. Of those that scrubbed on the first attempt, 75% launched on the second attempt. Thus it appears that, in general, a scrubbed vehicle is as good a candidate to launch as a fresh one. Of those vehicles which did have a second scrub, all the second scrubs occurred closer to launch in the countdown than the first scrub.

L. Causes for Scrubs:

Table II present detailed hold information by causes, ordered by time in the countdown. It will be observed that the principal causes for scrubs (X's) are discrepancies in Guidance and Control (31%), ground support equipment (23%), and vehicle propulsion systems (23%). Observe that all these scrubs occurred at or near ignition. The major cause of the Guidance and Control scrubs is gyro drift problems (usually apparent earlier in the countdown).

M. Failures Induced by Holds:

Fig. (3) presents hold rates in terms of average holds/minute of countdown time. These rates only apply as the countdown proceeds and are not directly applicable during holds. Two natural questions arise: (1) do secondary discrepancies occur during holds and (2) do later discrepancies arise due to the extended countdown duration incurred by previous holds?

In answer to question (1), though a hold for one cause is often used to catch up on latent discrepancies due to other causes, there is no direct evidence in the data indicating that new discrepancies arise during a hold. The only indication in this direction at all, is the scrub of Gemini GT-5 in which

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*Actually with a built-in hold at T = 10, some of the discrepancies for which holds were called later could have been corrected at this time, so that this percentage figure is probably on the low side.

problems with weather, tracking and spacecraft telemetry were all simultaneously present, despite a 31 minute hold to attempt to rectify them.

The second question can be approached as follows. Referring to Table IVC, we observe that except for Saturn I, instead of holds inducing further holds eventually resulting in scrubs, 50% or more of the scrubs occurred on the first hold. Referring to Table IVB for launches, we observe that for Thor-Delta and Gemini, that the probability of the occurrence of holds decreases monotonically with n; in fact the probability that a second hold occurred given that one hold occurred was zero for Gemini. For Saturn and Atlas, this second question can be approached by studying Figure 6. Observe that the total hold time distribution for Saturn launches is very close to a (truncated) normal distribution. This suggests that many uncorrelated causes go into making up this curve. It also indicates that the rate of "hold time fall off", on both sides of the mean, is the same. However, if increasing the countdown (as a result of holds) causes an increase in the discrepancy rate, one would expect that the curve to the right of the mean would tend upward (resulting in a skewed distribution). This does not occur on Saturn, but remarkably enough does occur on Atlas, where there is a distinct break in the distribution curve near the 50% point. In addition to these indications, examination of available data has failed to indicate any discrepancies that could be directly attributed to the extended countdown length associated with earlier holds.

Thus, except for Atlas* for which we have no detailed data, there is no direct indication that any discrepancies can be directly attributed to holds. Therefore there is also no direct indication that built-in holds incur substantial discrepancies either directly or by extending the countdown time.

N. Projection of Results to Other Vehicles

Projecting this data, it appears that for a launch vehicle such as Saturn V, which has very limited hold capabilities at countdown times later than 20 minutes before launch, a combination of built-in-holds (the last as

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*Computation of the conditional probabilities P(hold later in countdown | hold earlier in countdown), for Atlas and Saturn, tends to substantiate that the holds are uncorrelated.

late in the countdown as possible) combined with several launch window panes (to allow for recycling) would be highly desirable for increasing launch availability. Saturn V recycles to a countdown time of 20 minutes before ignition, if a discrepancy occurs in the last 20 minutes. Considering the median hold times found for Saturn I and IB, it appears that two launch window panes approximately one hour apart would be a reasonable compromise between (1) increasing launch availability and (2) minimizing range, trajectory, and software complexity, and payload loss.

O. Correlation of Unscheduled Holds with Countdown Activities:

No attempt has been made in this memo to correlate the occurrence of unscheduled holds with countdown activities. However, for better comparison between vehicle types, and as an aid in projecting the data to other vehicles, it would be helpful to normalize the countdown time with respect to critical countdown activities, such as the initiation and completion of propellent loading, and the start of the final launch sequence.

XI. SUMMARY

A statistical analysis was made for countdown hold data obtained from Saturn I and IB, Atlas SLV-3, Gemini and Thor-Delta Vehicle launches and launch attempts. This analysis was performed to provide background material for the consideration of "Launch on Time Strategies," and the effects of built-in-holds and varying launch windown sizes on launch availability.

Principal results are:

Launch Success and Hold Occurrence

	% Attempts Launched	% Launches on Time	Average No. of Holds/ Launch	Expected No. of Holds in Last 10 Minutes
Saturn I and IB	87	15	2.3	0.7
Atlas SLV-3	67	5	2.0	1.0
Gemini	75	58	0.6	0.6
Thor-Delta	72	52	0.4	0.7

Hold Lengths

	Total Hold Length not Exceeded by 95% of Launches	Median Hold Time for Individual Holds	
Saturn I and IB	190 mins.	27 mins. for 35	$T \leq 10$ mins. $T > 10$
Atlas SLV-3	130	15 66	$T \leq 40$ $T > 40$
Gemini	30	7 23	$T \leq 30$ $T > 30$
Thor-Delta	40	15 15	$T \leq 10$ $T > 10$

Principle Causes of Discrepancies

	Holds	Scrubs
Ground Support Equipment	18%	23%
Launch Vehicle Propulsion System	17%	23%
Guidance and Control	16%	31%
Range	11%	–

It was found that the variation of the rate of occurrence of holds as a function of countdown time, T (minutes before launch), was similar for all these vehicles. A composite approximation is:

Average Number of Holds per Minute of Countdown Time

$$\approx 0.05\ \delta(T) + \frac{0.3}{T+1},$$

where the delta function is associated with the failures at ignition.

From the available data (except for Atlas for which we have no detailed information) there is no direct indication that any discrepancies can be directly attributed to holds. Therefore, there is also no direct indication that built-in holds incur discrepancies either directly or because they extent the countdown time.

W. B. Gevarter

2014-WBG-$^{bjh}_{vh}$ W. B. Gevarter

REFERENCES

1. C. H. Eley, III, Bellcomm Working Papers on History of Launch Holds, 1967.

2. C. H. Eley, III, "Proposed Improvements in Countdown Flexibility for the Apollo-Saturn V Lunar Landing Mission", Bellcomm Memorandum For File, Case 140, September 30, 1965.

TABLE IA

JOB SBWBG

BASIC COUNTDOWN HOLD DATA

SATURN-I AND IB SERIES

VEH NO	ATTEMPT	LAUNCH=1 SCRUB=0	HOLD NO	TIME/CD*	LENGTH*	REASON
1.	1.	1.	1.	120.00	32.00	WEATHER
1.	1.	1.	2.	30.00	34.00	WEATHER
2.	1.	1.	1.	10.00	30.00	RANGE
3.	1.	1.	1.	75.00	45.00	POWER
4.	1.	1.	1.	100.00	20.00	GUIDANCE - CONTROL
4.	1.	1.	2.	65.00	40.00	TELEMETRY
4.	1.	1.	3.	19.00	42.00	PROPELENT LOADING
5.	1.	0.	1.	550.00	3.00	RANGE
5.	1.	0.	2.	520.00	17.00	POWER
5.	1.	0.	3.	430.00	27.00	GUIDANCE - CONTROL
5.	1.	0.	4.	260.00	20.00	PROCEDURE
5.	1.	0.	5.	240.00	-48.00**	PROPELENT LOADING
5.	2.	1.	1.	13.00	61.00	RANGE
6.	1.	0.	1.	795.00	128.00	VEH PROPULSION SYS
6.	1.	0.	2.	545.00	25.00	POWER
6.	1.	0.	3.	115.00	-0.01	VEHICLE
6.	2.	1.	1.	85.00	38.00	GUIDANCE - CONTROL
6.	2.	1.	2.	70.00	60.00	PROPELENT LOADING
6.	2.	1.	3.	4.00	1.00	PROPELENT LOADING
6.	2.	1.	4.	0.68	75.00	GUIDANCE - CONTROL
7.	1.	1.	1.	245.00	69.00	VEHICLE
7.	1.	1.	2.	30.00	4.00	VEH PROPULSION SYS
7.	1.	1.	3.	12.00	20.00	VEHICLE
7.	1.	1.	4.	5.00	49.00	RANGE
8.	1.	1.	0.	0.	0.	NO HOLDS OCCUR
9.	1.	1.	1.	30.00	30.00	POWER
9.	1.	1.	2.	26.00	67.00	POWER
10.	1.	1.	0.	0.	0.	NO HOLDS OCCUR
201.	1.	1.	1.	266.00	30.00	GRND SUPPORT EQUIP
201.	1.	1.	2.	90.00	30.00	VEH PROPULSION SYS
201.	1.	1.	3.	30.00	78.00	PROCEDURE
201.	1.	1.	4.	4.00	73.00	VEH PROPULSION SYS
201.	1.	1.	5.	5.50	31.00	VEH PROPULSION SYS
202.	1.	1.	1.	545.00	60.00	GRND SUPPORT EQUIP
202.	1.	1.	2.	424.00	40.00	GRND SUPPORT EQUIP
202.	1.	1.	3.	20.00	41.00	RANGE
202.	1.	1.	4.	3.00	4.00	POWER
203.	1.	1.	1.	15.00	12.50	PAYLOAD
203.	1.	1.	2.	5.00	88.50	PAYLOAD
203.	1.	1.	3.	3.00	2.00	RANGE

*COUNTDOWN TIME GIVEN IN MINUTES BEFORE LAUNCH, HOLD LENGTH IS IN MINUTES

**MINUS SIGNS INDICATE A SCRUB OCCURS ON THAT HOLD

JCB 58W8G

TABLE 13 - BASIC COUNTDOWN HOLD DATA

ATLAS SLV-3

VEH NO	ATTEMPT	LAUNCH=1 SCRUB=0	HOLD NO	TIME/CD*	LENGTH	REASON
7101.	3.	1.	1.	175.00	63.00	NO DATA FOR CASE
7101.	3.	1.	2.	70.00	28.00	NO DATA FOR CASE
7101.	3.	1.	3.	12.50	29.00	NO DATA FOR CASE
7101.	3.	1.	4.	3.50	2.00	NO DATA FOR CASE
7102.	1.	1.	1.	55.00	51.00	NO DATA FOR CASE
7102.	1.	1.	2.	17.50	4.00	NO DATA FOR CASE
7102.	1.	1.	3.	3.50	4.00	NO DATA FOR CASE
7102.	1.	1.	4.	1.50	20.00	NO DATA FOR CASE
7102.	1.	1.	5.	0.50	31.00	NO DATA FOR CASE
7103.	1.	1.	1.	55.00	60.00	NO DATA FOR CASE
7103.	1.	1.	2.	12.50	6.00	NO DATA FOR CASE
7105.	1.	0.	1.	55.00	65.00	NO DATA FOR CASE
7105.	1.	0.	2.	25.00	30.00	NO DATA FOR CASE
7105.	1.	0.	3.	8.00	-93.00	NO DATA FOR CASE
7105.	2.	1.	1.	17.50	20.00	NO DATA FOR CASE
7105.	2.	1.	2.	3.50	5.00	NO DATA FOR CASE
7106.	1.	1.	1.	55.00	60.00	NO DATA FOR CASE
7106.	1.	1.	2.	7.50	5.00	NO DATA FOR CASE
7104.	1.	0.	1.	60.00	-40.00	NO DATA FOR CASE
7104.	2.	1.	1.	70.00	78.00	NO DATA FOR CASE
7104.	2.	1.	2.	12.50	7.00	NO DATA FOR CASE
7401.	1.	1.	1.	70.00	180.00	NO DATA FOR CASE
7401.	1.	1.	2.	7.50	24.00	NO DATA FOR CASE
7107.	1.	1.	1.	70.00	85.00	NO DATA FOR CASE
7107.	1.	1.	2.	7.50	2.00	NO DATA FOR CASE
7108.	1.	1.	1.	17.50	90.00	NO DATA FOR CASE
7109.	1.	0.	1.	70.00	40.00	NO DATA FOR CASE
7109.	1.	0.	2.	10.00	-105.00	NO DATA FOR CASE
7109.	2.	1.	1.	7.50	30.00	NO DATA FOR CASE
7109.	2.	1.	2.	0.50	19.00	NO DATA FOR CASE
7112.	1.	1.	1.	7.50	18.00	NO DATA FOR CASE
7112.	1.	1.	2.	1.50	1.00	NO DATA FOR CASE
7111.	1.	1.	1.	7.50	15.00	NO DATA FOR CASE
7110.	1.	0.	1.	240.00	-164.00	NO DATA FOR CASE
7110.	2.	0.	1.	70.00	44.00	NO DATA FOR CASE
7110.	2.	0.	2.	35.00	4.00	NO DATA FOR CASE
7110.	2.	0.	3.	12.50	-12.00	NO DATA FOR CASE
7110.	3.	1.	1.	35.00	4.00	NO DATA FOR CASE
7110.	3.	1.	2.	12.50	12.00	NO DATA FOR CASE
7110.	3.	1.	3.	1.50	1.00	NO DATA FOR CASE
7110.	3.	1.	4.	0.50	3.50	NO DATA FOR CASE
7113.	1.	1.	1.	12.50	9.00	NO DATA FOR CASE
7114.	1.	1.	1.	12.50	25.50	NO DATA FOR CASE
7115.	1.	0.	1.	112.00	-0.01	NO DATA FOR CASE
7115.	2.	1.	1.	25.00	38.00	NO DATA FOR CASE
7116.	1.	1.	1.	12.50	10.00	NO DATA FOR CASE
7116.	1.	1.	2.	1.50	26.00	NO DATA FOR CASE
7117.	1.	1.	1.	25.00	32.00	NO DATA FOR CASE
7118.	1.	1.	0.	0.	0.	NO HOLDS OCCUR

*BASIC COUNTDOWN TIME DATA WAS GIVEN ONLY IN INTERVALS. THEREFORE, TIME SHOWN IS THAT AT CENTER OF THE INTERVAL.

TABLE I C

BASIC COUNTDOWN HOLD DATA

GEMINI

VEH NO	ATTEMPT	LAUNCH=1 SCRUB=0	HOLD NO	TIME/CD	LENGTH	REASON
1.	1.	1.	0.	.00	.00	NO HOLDS OCCUR
2.	1.	0.	1.	500.00	120.00	PROPELLENT LOADING
2.	1.	0.	2.	175.00	11.00	POWER
2.	1.	0.	3.	37.00	20.00	PROCEDURE
2.	1.	0.	4.	6.00	11.00	PAYLOAD PROPUL.SYS
2.	1.	0.	5.	.02	-.01	VEHICLE
2.	2.	1.	1.	5.00	4.00	PAYLOAD PROPUL.SYS
3.	1.	1.	1.	35.00	24.00	VEH PROPULSION SYS
4.	1.	1.	1.	35.00	76.00	GRND SUPPORT EQUIP
5.	1.	0.	1.	300.00	180.00	PAYLOAD PROPUL.SYS
5.	1.	0.	2.	75.00	20.00	BUILT IN HOLD
5.	1.	0.	3.	10.00	-31.00	COMBINED FACTORS
5.	2.	1.	1.	75.00	20.00	BUILT IN HOLD
6.	1.	0.	1.	3.00	6.00	BUILT IN HOLD
6.	1.	0.	2.	.02	-.01	GRND SUPPORT EQUIP
6.	2.	1.	1.	3.00	6.00	BUILT IN HOLD
7.	1.	1.	1.	3.00	6.00	BUILT IN HOLD
8.	1.	1.	1.	3.00	6.00	BUILT IN HOLD
9.	1.	0.	1.	3.00	6.00	BUILT IN HOLD
9.	1.	0.	2.	3.00	2.00	GUIDANCE - CONTROL
9.	1.	0.	3.	3.00	4.00	GUIDANCE - CONTROL
9.	1.	0.	4.	3.00	-5.00	GUIDANCE - CONTROL
9.	2.	1.	1.	3.00	6.00	BUILT IN HOLD
9.	2.	1.	2.	3.00	2.00	GUIDANCE - CONTROL
10.	1.	1.	1.	3.00	6.00	BUILT IN HOLD
11.	1.	1.	1.	97.00	16.00	PAYLOAD
11.	1.	1.	2.	3.00	6.00	BUILT IN HOLD
12.	1.	1.	1.	3.00	6.00	BUILT IN HOLD

B •SBWBG

TABLE ID

BASIC COUNTDOWN HOLD DATA

THOR DELTA

VEH NO	ATTEMPT	LAUNCH=1 SCRUB=0	HOLD NO	TIME/CD	LENGTH	REASON
1.	1.	0.	1.	15.00	-28.00	GUIDANCE - CONTROL
1.	2.	1.	1.	15.00	5.00	WEATHER
2.	1.	0.	1.	25.00	-23.00	PROCEDURE
2.	2.	0.	1.	1.17	19.00	RANGE
2.	2.	0.	2.	2.00	-15.00	VEH PROPULSION SYS
2.	3.	1.	1.	28.00	22.00	VEH PROPULSION SYS
3.	1.	1.	0.	0.	0.	NO HOLDS OCCUR
4.	1.	1.	0.	0.	0.	NO HOLDS OCCUR
5.	1.	1.	0.	0.	0.	NO HOLDS OCCUR
6.	1.	1.	1.	3.00	2.00	RANGE
6.	1.	1.	2.	8.00	4.00	RANGE
7.	1.	0.	1.	30.00	12.00	PROCEDURE
7.	1.	0.	2.	9.00	-45.00	GRND SUPPORT EQUIP
7.	2.	0.	1.	2.00	-47.00	GUIDANCE - CONTROL
7.	3.	1.	1.	12.00	37.00	VEHICLE
8.	1.	0.	1.	0.	-60.00	VEH PROPULSION SYS
8.	2.	1.	1.	8.00	5.00	RANGE
9.	1.	0.	1.	6.00	-166.00	VEH PROPULSION SYS
9.	2.	1.	1.	0.	45.00	VEH PROPULSION SYS
10.	1.	1.	1.	13.00	120.00	VEH PROPULSION SYS
10.	1.	1.	2.	2.00	14.00	VEH PROPULSION SYS
11.	1.	1.	0.	0.	0.	NO HOLDS OCCUR
12.	1.	1.	1.	0.23	9.00	GRND SUPPORT EQUIP
13.	1.	1.	1.	0.12	6.00	PROPELENT LOADING
14.	1.	1.	0.	0.	0.	NO HOLDS OCCUR
15.	1.	1.	0.	0.	0.	NO HOLDS OCCUR
16.	1.	1.	1.	1.23	12.00	POWER
16.	1.	1.	2.	0.17	7.00	GRND SUPPORT EQUIP
17.	1.	1.	0.	0.	0.	NO HOLDS OCCUR
18.	1.	1.	0.	0.	0.	NO HOLDS OCCUR
19.	1.	1.	0.	0.	0.	NO HOLDS OCCUR
20.	1.	0.	1.	4.00	-28.00	GUIDANCE - CONTROL
20.	2.	1.	0.	0.	0.	NO HOLDS OCCUR
21.	1.	1.	0.	0.	0.	NO HOLDS OCCUR

TABLE II

UNSCHEDULED HOLDS BY CAUSES
(Ordered by Time in Countdown ~ Mins. Before Launch)

Vehicle	Weather		Range		TM		Combined Factors		G & C		Power		Propellent Loading GSE		Vehicle Propulsion		Payload Propulsion		Vehicle Other		Payload Other		GSE Other		Procedure	
	T	H	T	H	T	H	T	H	T	H	T	H	T	H	T	H	T	H	T	H	T	H	T	H	T	H
Saturn I and IB			3 5	2 49					0.7	75	3	4	4	1	4 5.5	73 31					5	88				
	30 120	34 32	10 13 20 550	30 61 41 3	65	40			85 100 430	38 20 27	26 30 75 520 545	67 30 45 17 25	19 70 240	42 60 X	30 90 795	4 30 128			12 115 245	20 X 69	15	12	266 424 545	30 40 60	30 260	78 20
Gemini									3 3 3 3	2 2 4 X							5 6	4 11	0	X			0	X		
							10	X			175	11	500	120	35	24	300	180			97	16	35	76	37	20
Thor*			1 3 8 8	19 2 4 5					2 4	X X	1.2	12	0.1	6	0 0 2 2 6	45 X 14 X X							0.2 0.2 9	7 9 X		
	15	5							15	X					13 28	120 22			12	37					25 30	X 12
No. of Scrubs Median Time of Scrubs									3	4			240	1	2	3			57	2			4	2	25	1

*All Holds at T < 8 Recycled to T = 8, Recycle Time Not included. X means Scrub H = Hold Time in mins.

TABLE IIIA

NUMBER OF UNSCHEDULED HOLDS BY CAUSES

VEHICLE	WEATHER	RANGE	TM	COMBINED FACTORS	G.& C.	POWER	PROP. LOADING GSE	VEHICLE PROPULSION	PAYLOAD PROPULSION	VEHICLE OTHER	PAYLOAD OTHER	GSE OTHER	PROCEDURE
SATURN	2	6	1		4	6	4	5		3	2	3	2
GEMINI				1	4	1	1	1	3	1	1	2	1
THOR	1	4			3	1	1	7		1		3	2
TOTAL	3	10	1	1	11	8	6	13	3	5	3	8	5

TABLE III B

UNSCHEDULED HOLD CAUSE FREQUENCY ~ PERCENT

Vehicle	Weather	Range	TM	Combined Factors	G.&C.	Power	Prop. Loading GSE	Vehicle Propulsion	Payload Propulsion	Vehicle Other	Payload Other	GSE Other	Procedure
Saturn	5.3	15.8	2.6	—	10.5	15.8	10.5	13.2	—	7.9	5.3	7.9	5.3
Atlas	No Data												
Gemini	—	—	—	6.2	25.0	6.2	6.2	6.2	18.8	6.2	6.2	12.5	6.2
Thor	4.3	17.4	—	—	13.0	4.3	4.3	30.4	—	4.3	—	13.0	8.7
Average of above	3.2	11.1	.9	2.1	16.2	8.8	7.0	16.6	6.2	6.1	3.8	11.1	6.7

TABLE IVA

NO. OF UNSCHEDULED HOLDS

Vehicle in Sequence	LAUNCHES Saturn I	LAUNCHES Saturn IB	LAUNCHES Atlas SLV-3	LAUNCHES Thor Delta	LAUNCHES Gemini	SCRUBS*** Saturn I	SCRUBS*** Atlas SLV-3	SCRUBS*** Thor Delta	SCRUBS*** Gemini
1	2	5	4	1	0		* / *	1	
2	1	4	5	1	1			1 / 2	5
3	1	3	2	0	1				
4	3		2	0	1		3		
5	1		2	0	0	5			2
6	4		2	2	0	3	1		1
7	4		2	1	0			2 / 1	
8	0		2	1	0			1	
9	2		1	1	1			1	1**
10	0		2	2	0		2		
11			2	0	1				
12			1	1	0				
13			4	1			1 / 3		
14			1	0					
15			1	0			1		
16			1	2					
17			2	0					
18			1	0					
19			0	0					
20				0				1	
21				0					
AVG. HOLDS/LAUNCH	1.80	4.00	1.95	.62	.42				
AVG. HOLDS/SCRUB	4.00	-	1.83	1.25	2.25				
EXPECTED NO. OF HOLDS FOR COMPLETE COUNT-DOWN	1.91	4.00	2.28	0.93	1.05				
	$\underbrace{\quad\quad}_{2.80}$								

*UNKNOWN

**3 SUCCESSIVE HOLDS FOR IGS UPDATE

***INCLUDES HOLD AT SCRUB

TABLE IV B

PROBABILITIES OF NUMBER OF HOLDS PER LAUNCH

VEHICLE	$P(n=0)$	$P(n=1)$	$P(n=2)$	$P(n=3)$	$P(n=4)$	$P(n=5)$	$P(n\geq 2/n\geq 1)$	$P(n\geq 3/n\geq 2)$
SATURN I	.20	.30	.20	.10	.20	-	.62	.60
ATLAS SLV-3	.05	.32	.47	0	.11	.05	.66	.25
THOR-DELTA	.52	.33	.14	-	-	-	.30	0
GEMINI	.58	.42	-	-	-	-	0	-

TABLE IV C

PROBABILITIES OF NUMBER OF HOLDS PER SCRUB
(INCLUDES HOLD FOR SCRUB)

VEHICLE	P(n=1)	P(n=2)	P(n=3)	P(n=4)	P(n=5)
SATURN I	0	0	.50	.50	-
ATLAS SLV-3	.50	.17	.33	-	-
THOR-DELTA	.75	.25	-	-	-
GEMINI	.50	.25	0	0	.25

TABLE V

LAUNCH SUCCESS DATA

Vehicle	No. of Launch Attempts	No. of Scrubs	No. of Launches	No. of L.O.T.***	No. of Scrubs at Launch	No. of Launches Having Holds at T < 1 min.	No. of Launches Having Holds at T < 10 mins.	% Attempts Launched	% Launches That L.O.T.	% Launches L.O.T. If Hold at T = 1 min.	% Launches L.O.T. If Hold at T = 10 mins.	% Vehicles Brought to Launch that Scrubbed at Launch
	Basic Data							Percentages				
Saturn I and IB	15	2	13	2	0	0	5	87	15	100	61	0
Atlas SLV-3	27*	8*	19	1	0	3	11	67*	5	84	42	0
Gemini	16	4	12	7	2	0	2**	75	58	100	83	14
Thor Delta	29	8	21	11	1	4	7	72	52	81	67	5
Average of Above								75	35	91	63	5

*Includes first two attempts of Vehicle 7101.
**Exludes built-in holds.
***Launch on time.

TABLE VI

NO. OF TRIES FOR LAUNCH

Vehicle	No. of Vehicles Launched 1st Try	2nd Try	3rd Try	% Vehicles Launched on 1st Try	% of First Scrubs Launched on Next Try	% 2nd Scrub That Occurred Later in Countdown than 1st
Saturn I and IB	11	2		85	100	—
Atlas SLV-3	13	4	2*	68	50	100
Gemini	8	4		67	100	—
Thor Delta	15	4	2	72	50	100
Avg. of Above				73%	75%	100%

*Includes first two attempts of Vehicle 7101.

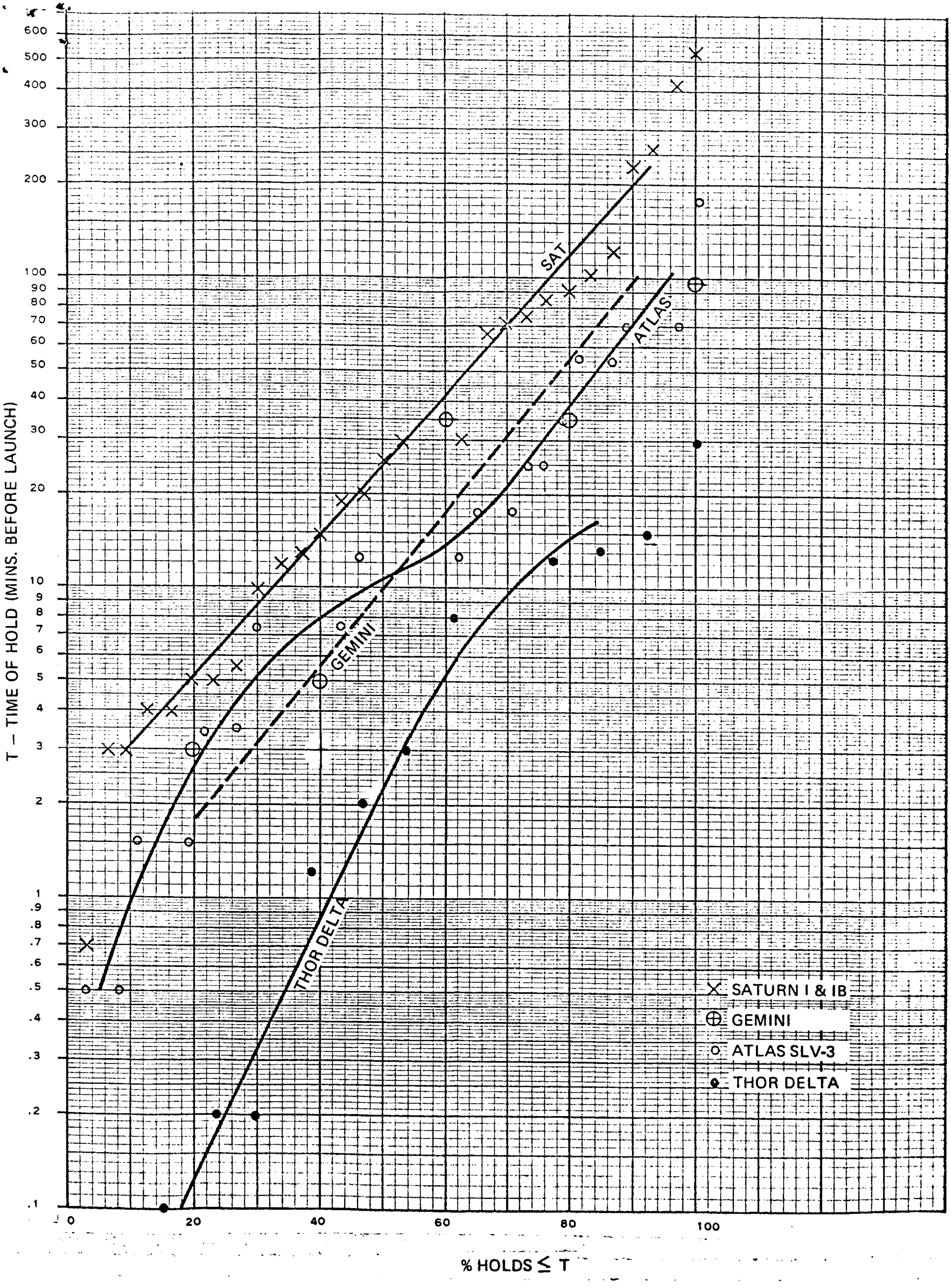

Figure 1 – COUNTDOWN TIME OF UNSCHEDULED HOLDS, LAUNCHES ONLY

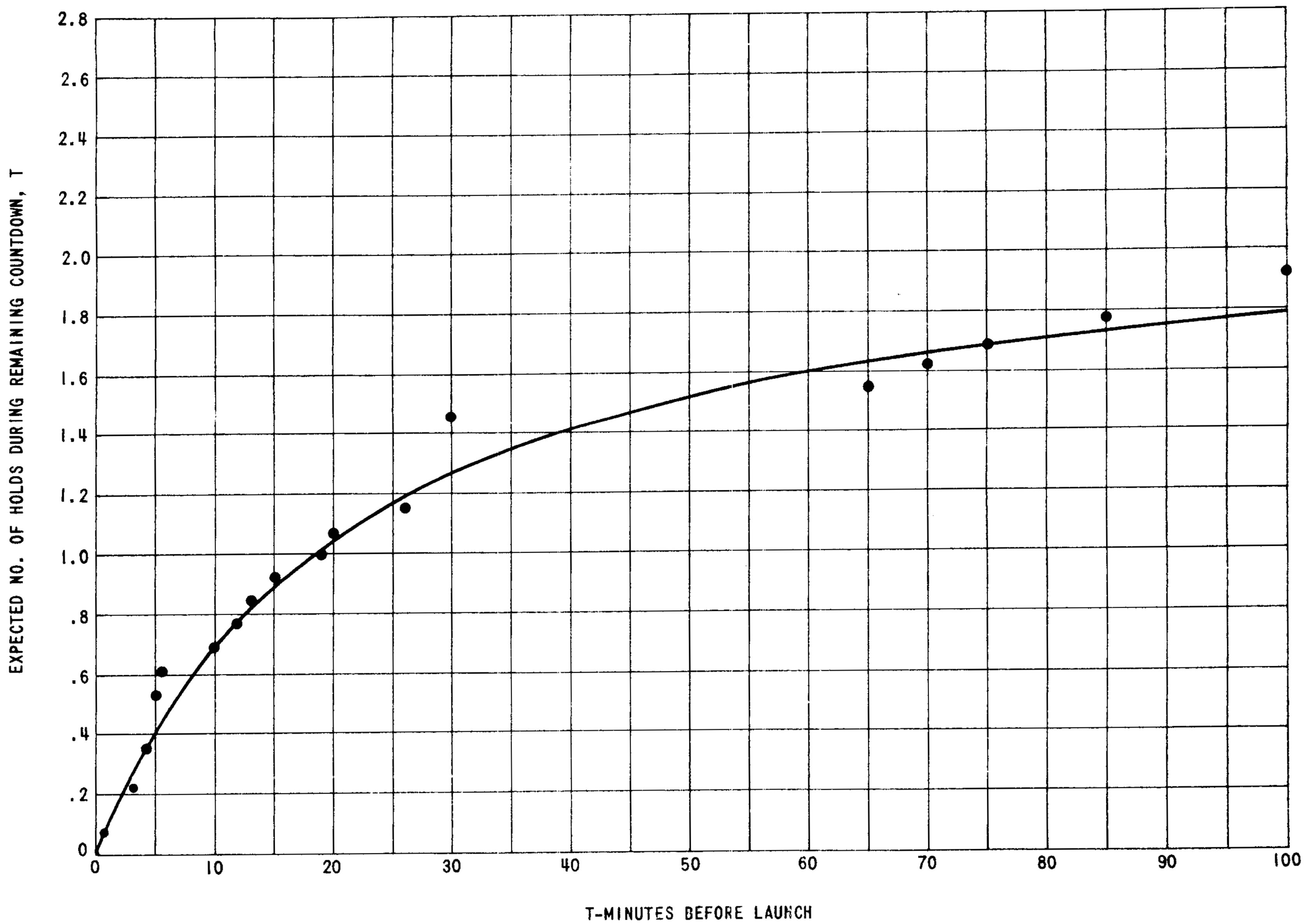

FIGURE 2a - EXPECTED VALUE OF NO. OF REMAINING UNSCHEDULED HOLDS FOR A COMPLETE COUNTDOWN - SATURN I AND IB

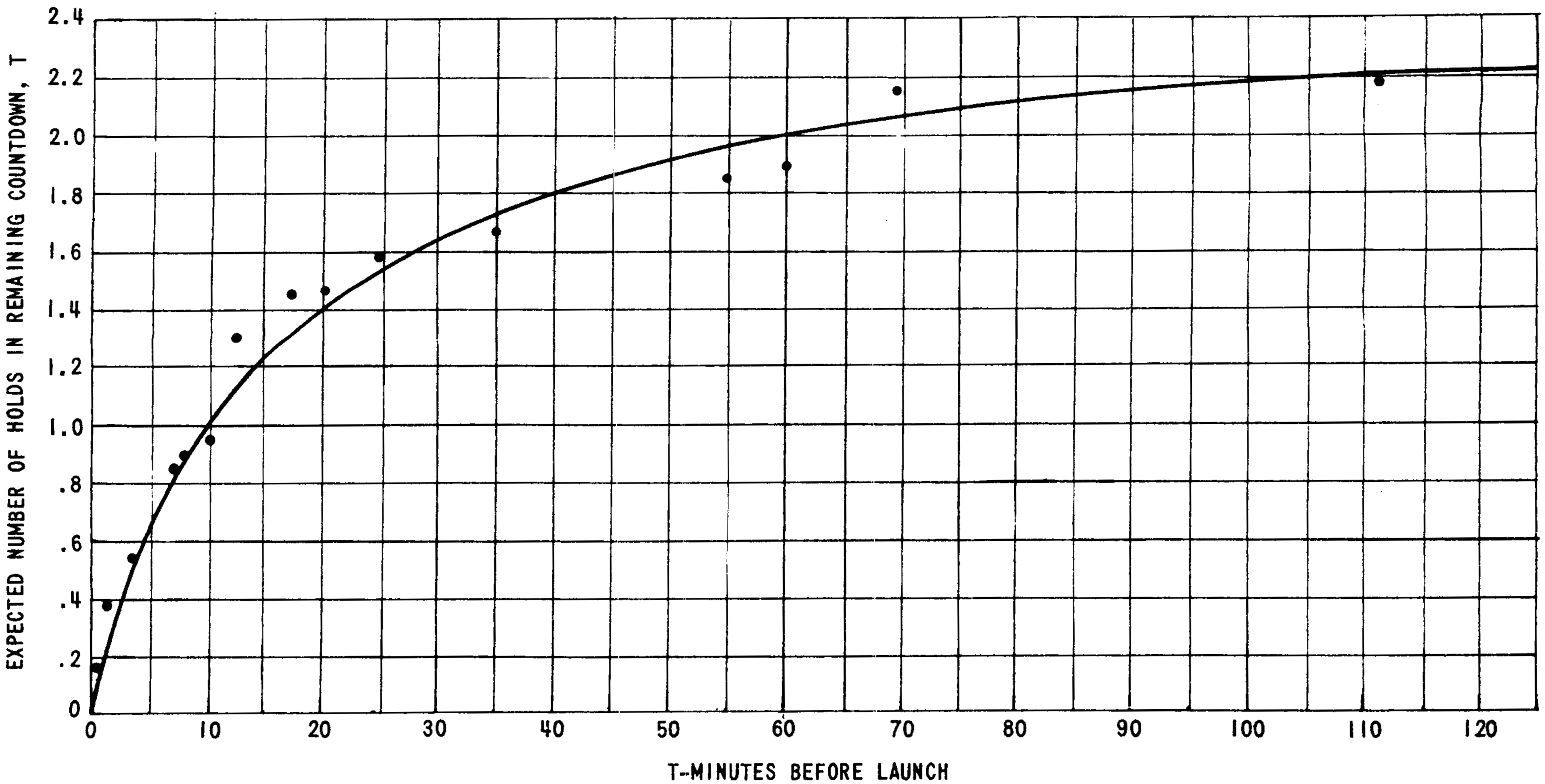

FIGURE 2b - EXPECTED VALUE OF NUMBER OF REMAINING HOLDS - ATLAS

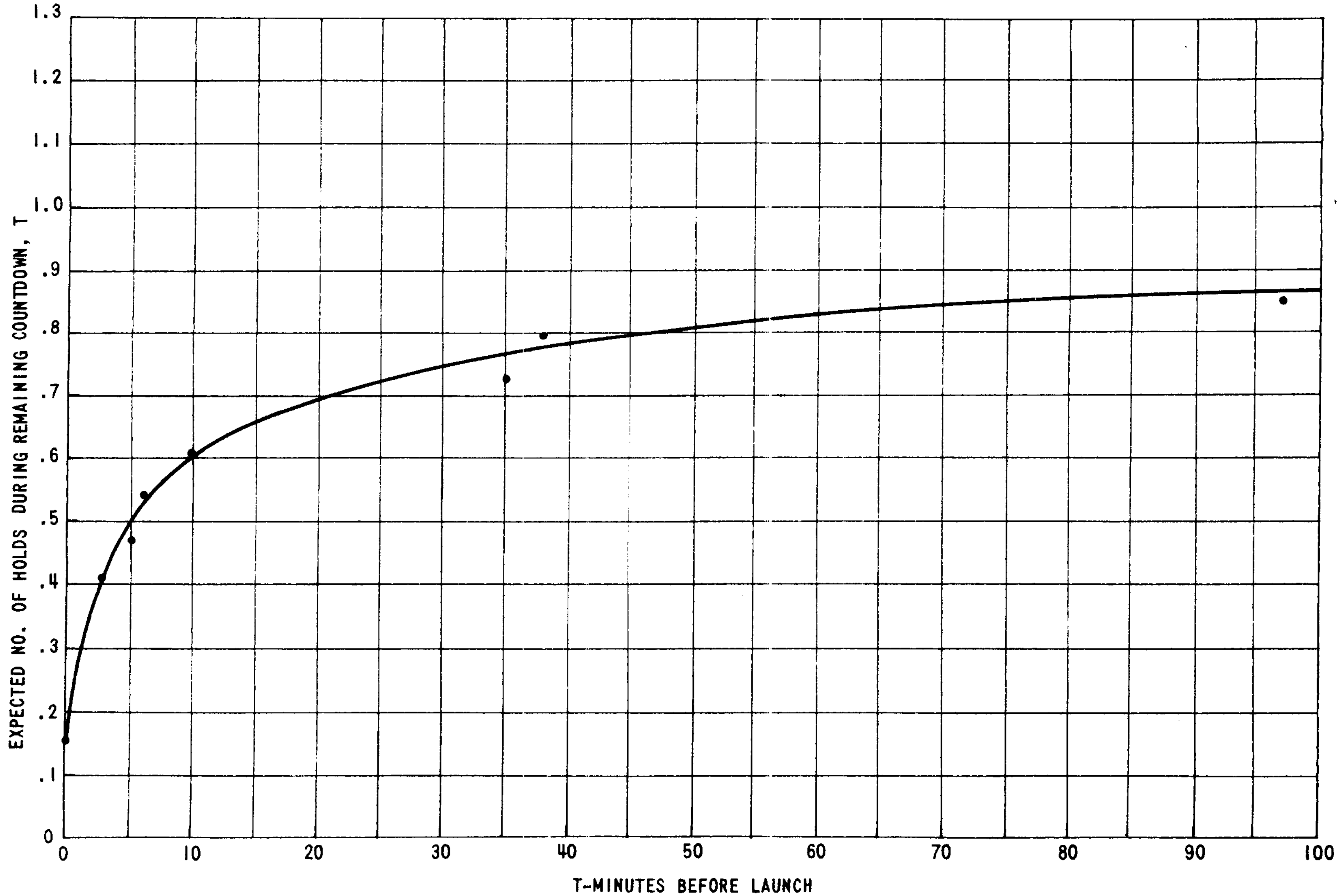

FIGURE 2c - EXPECTED VALUE OF NO. OF REMAINING UNSCHEDULED HOLDS - GEMINI

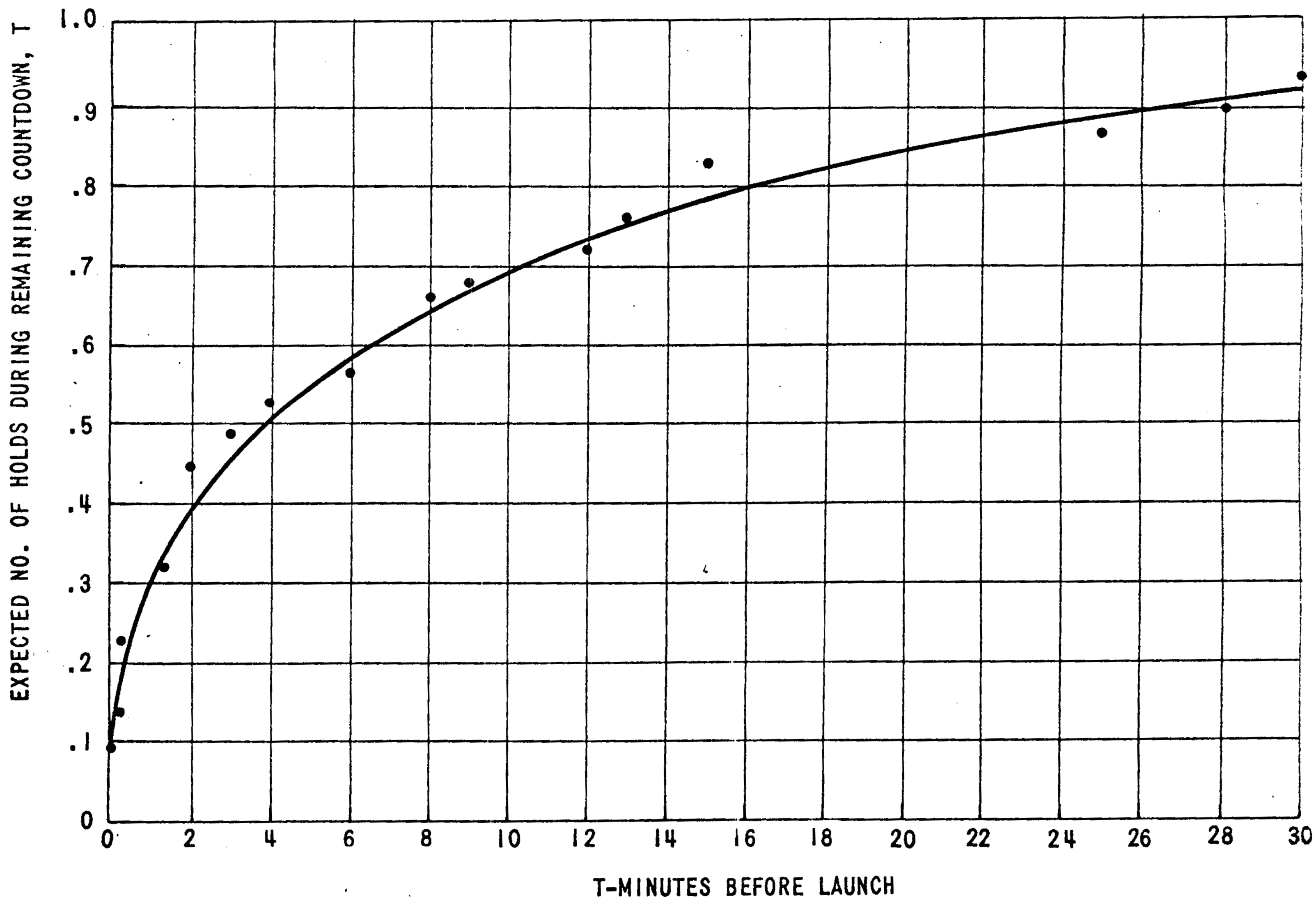

FIGURE 2d - EXPECTED VALUE OF NO. OF REMAINING UNSCHEDULED HOLDS - THOR DELTA

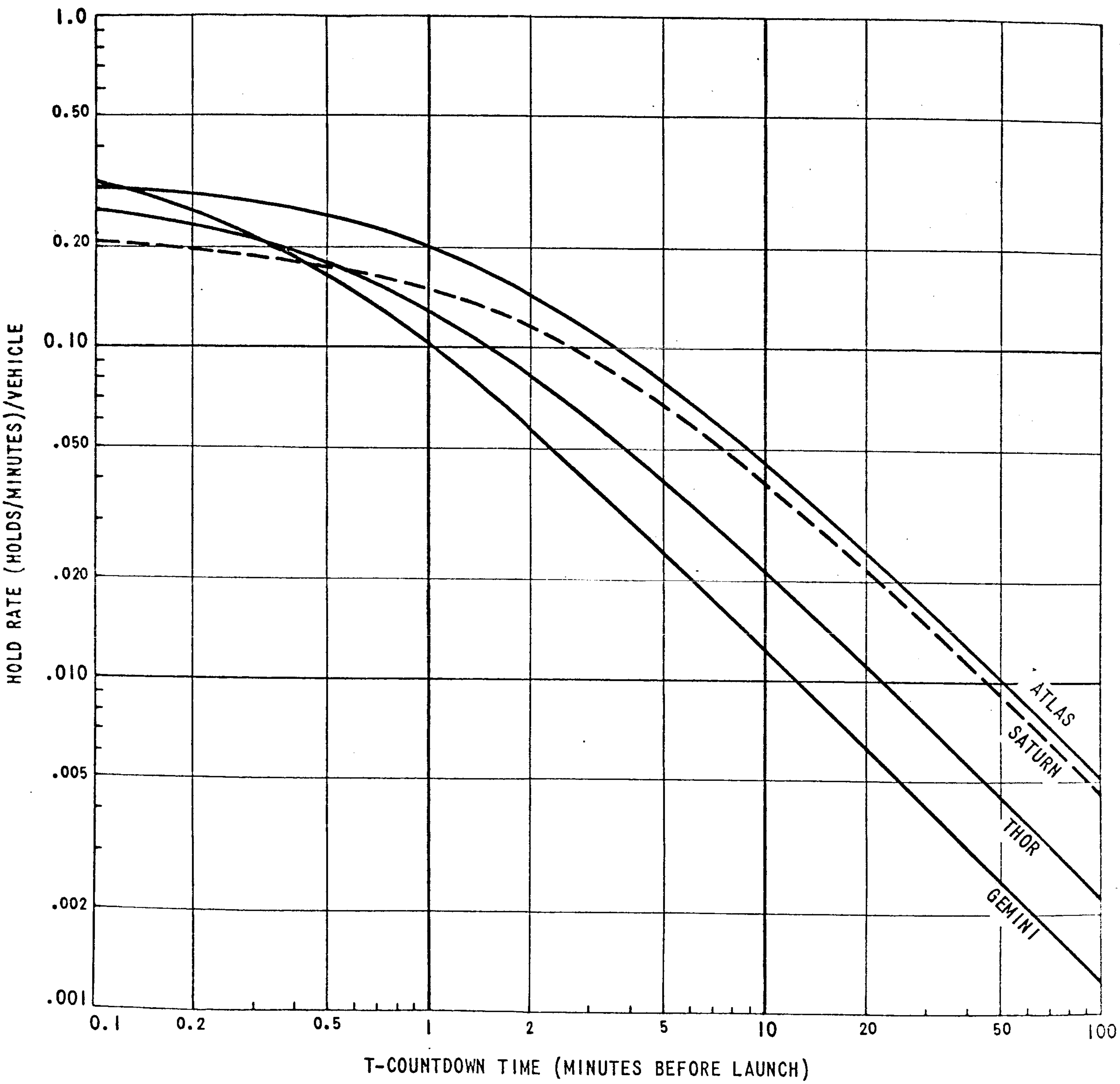

FIGURE 3 - HOLD RATES

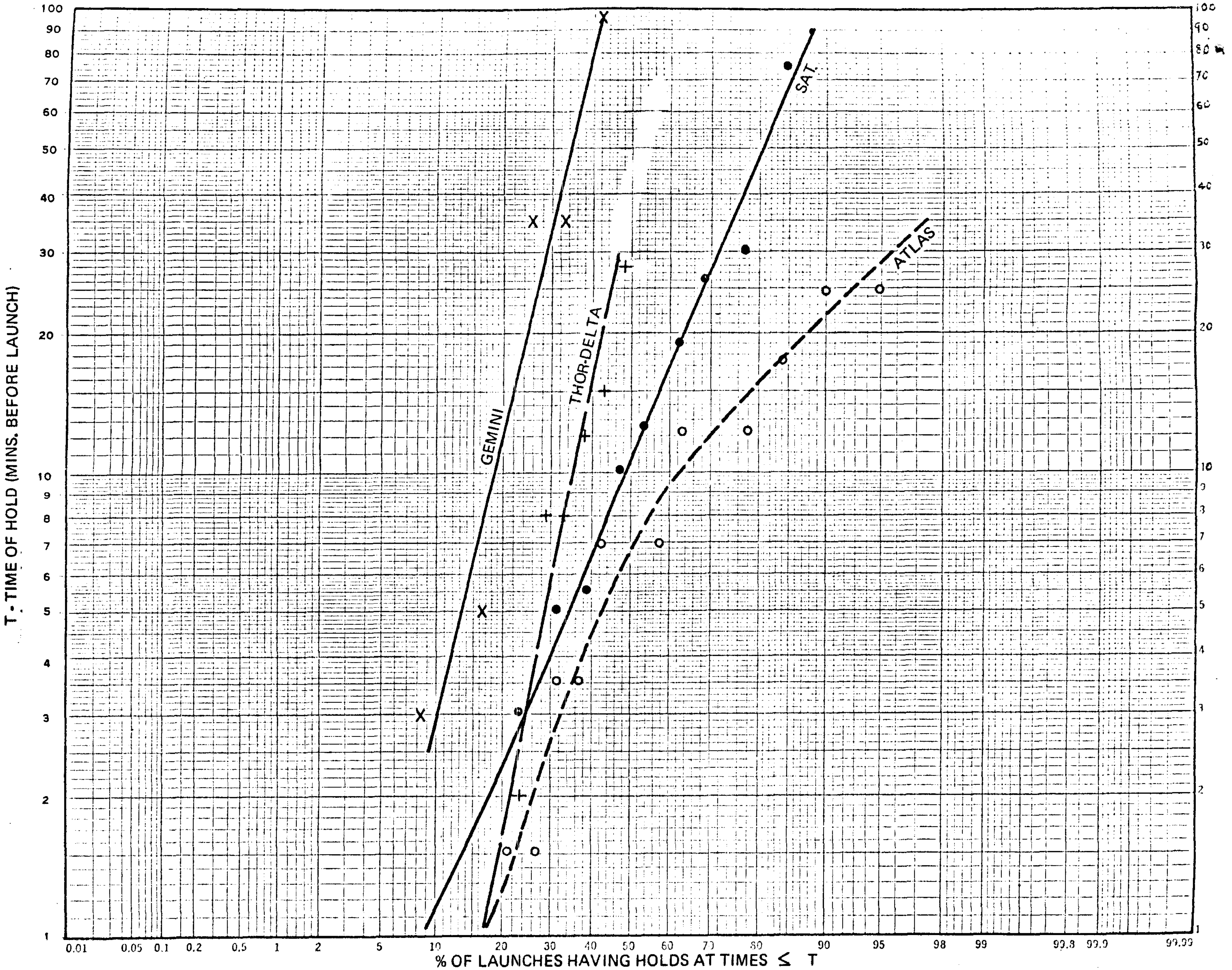

Figure 4 — TIME OF LAST UNSCHEDULED HOLD, LAUNCHES ONLY

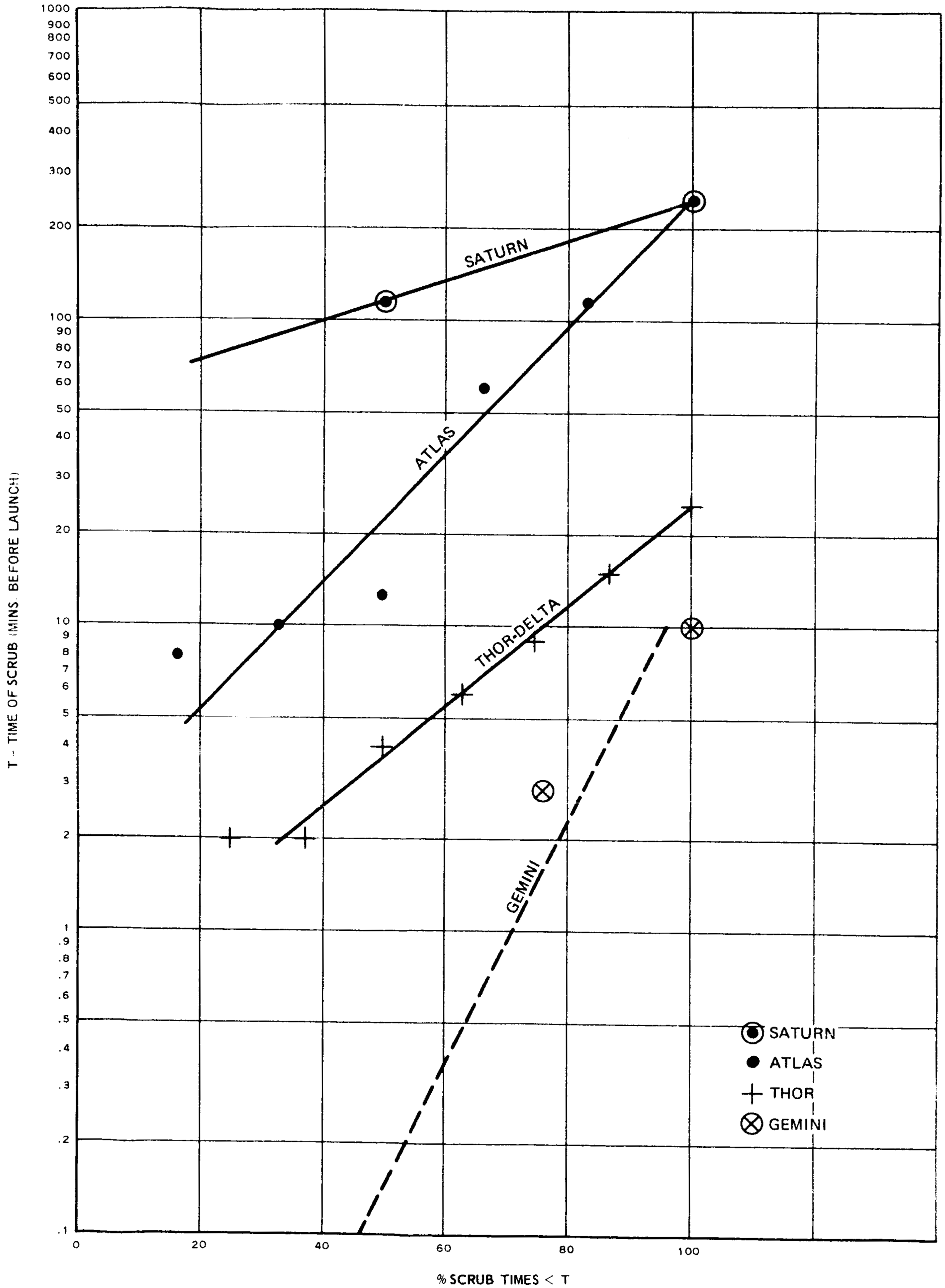

Figure 5 – TIME OF SCRUB

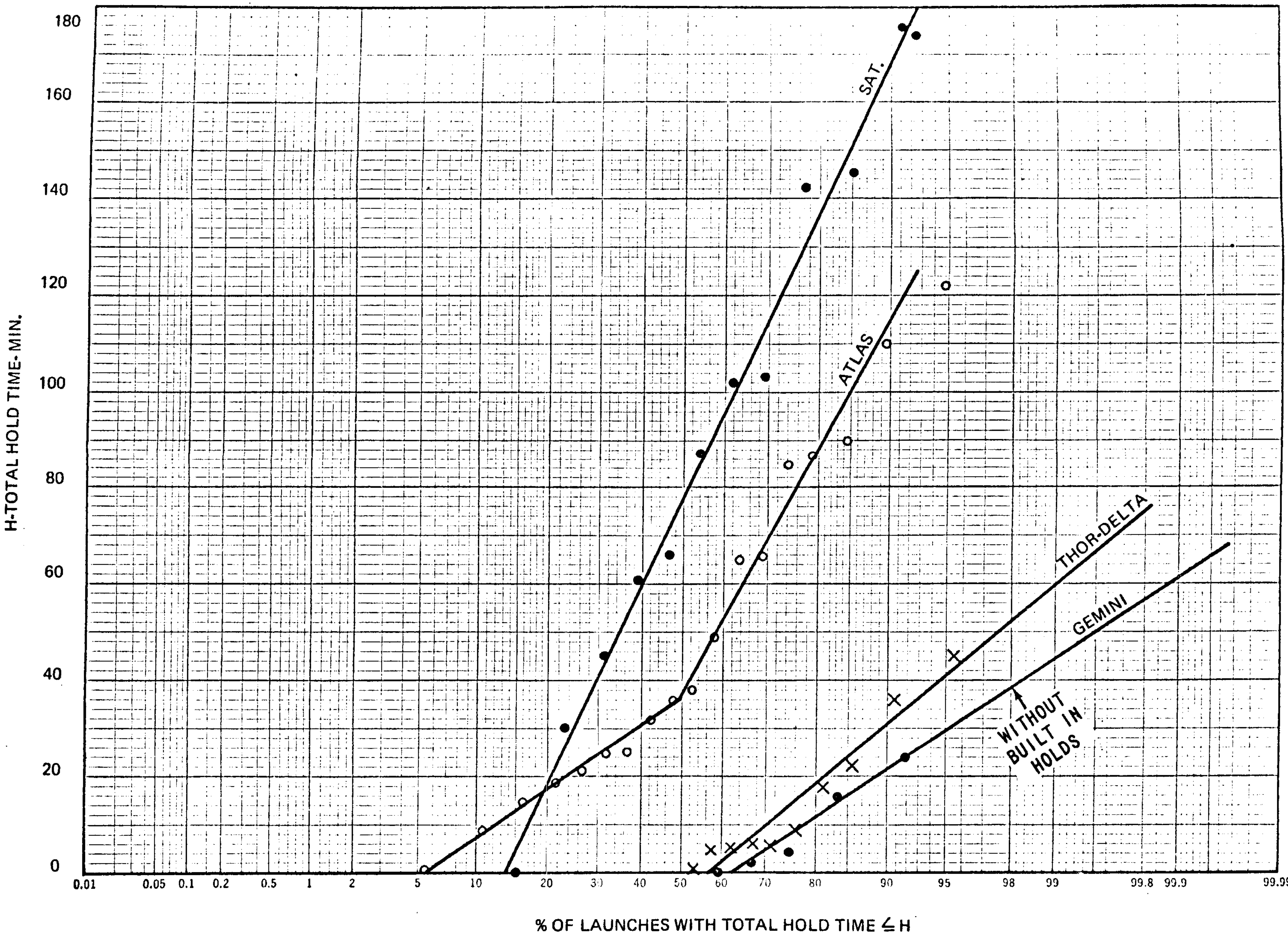

Figure 6 — TOTAL HOLD TIME, LAUNCHES ONLY

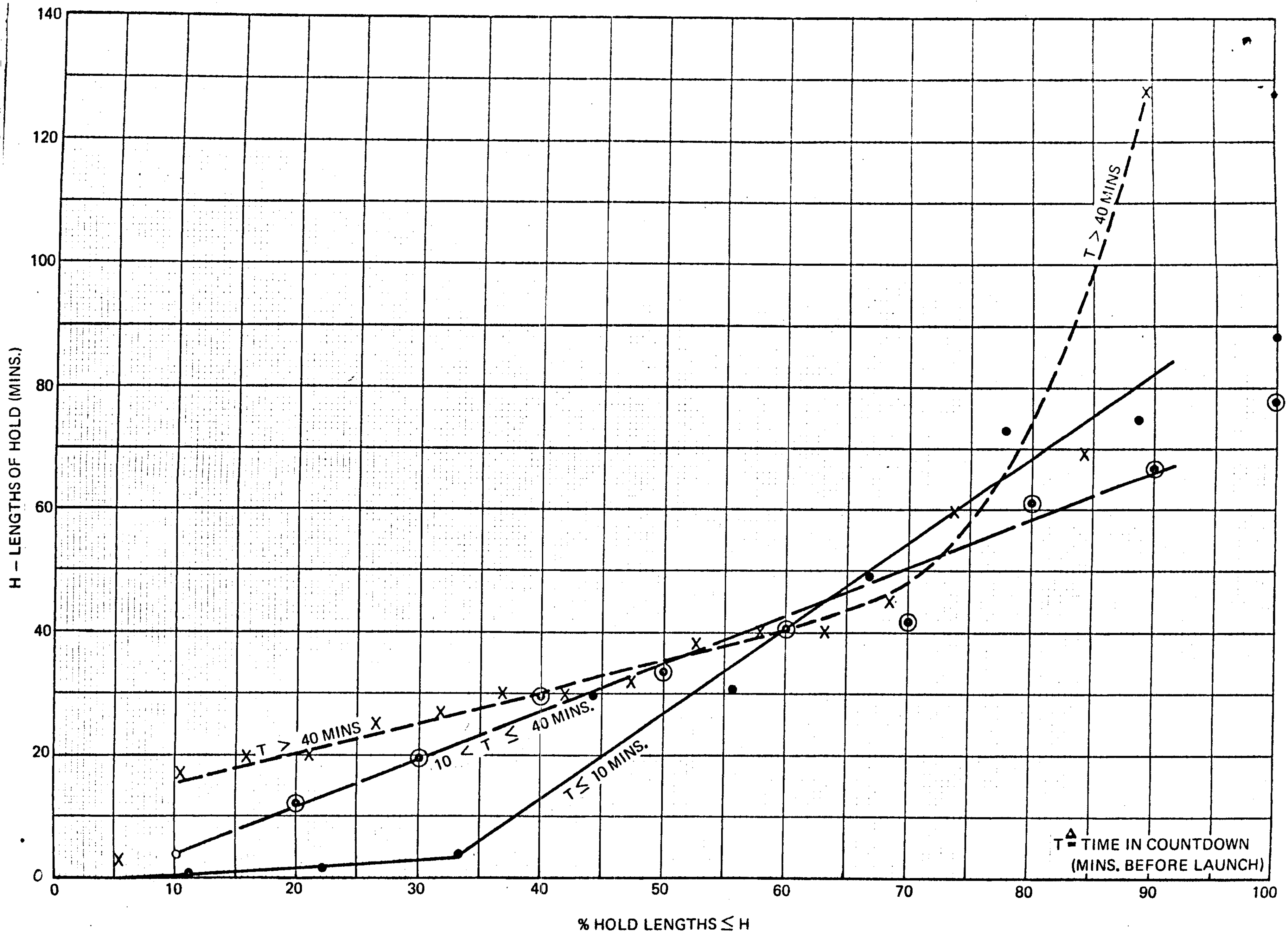

Figure 7a – LENGTHS OF HOLDS FOR LAUNCHES AND SCRUBS – SATURN I AND IB

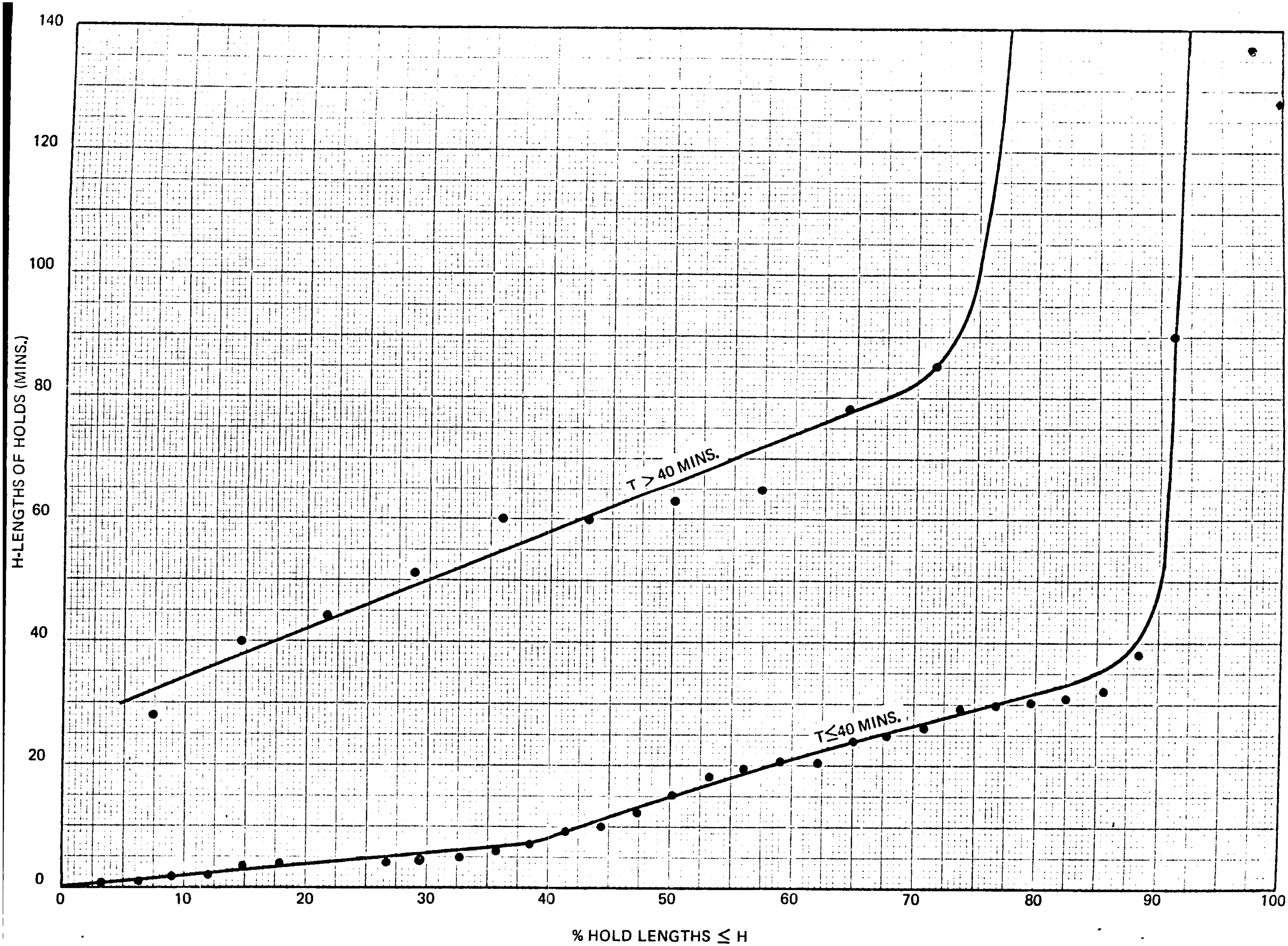

Figure 7b – LENGTHS OF HOLDS FOR LAUNCHES AND SCRUBS – ATLAS SLV-3

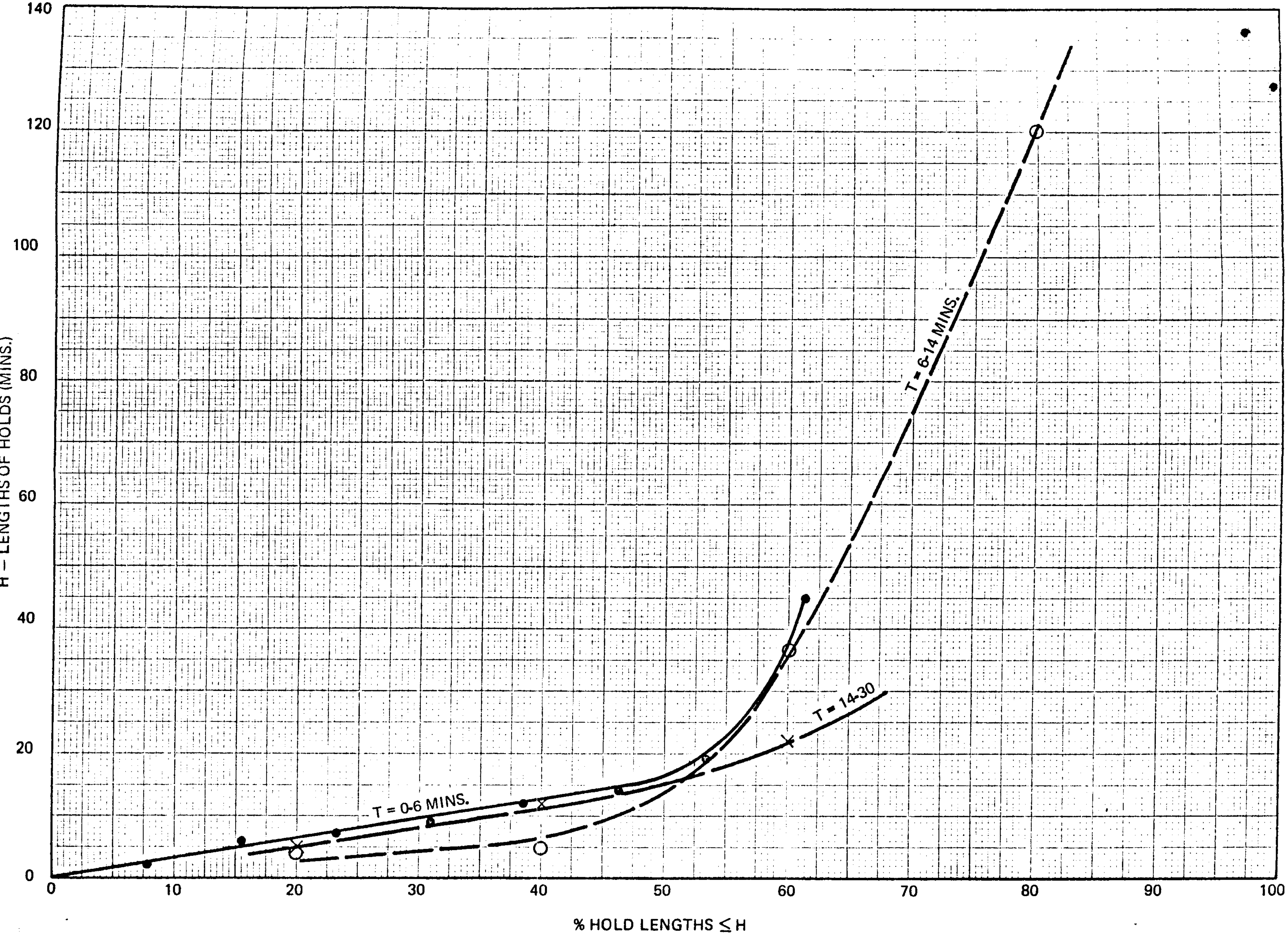

Figure 7c – LENGTHS OF HOLDS FOR LAUNCHES AND SCRUBS-THOR-DELTA

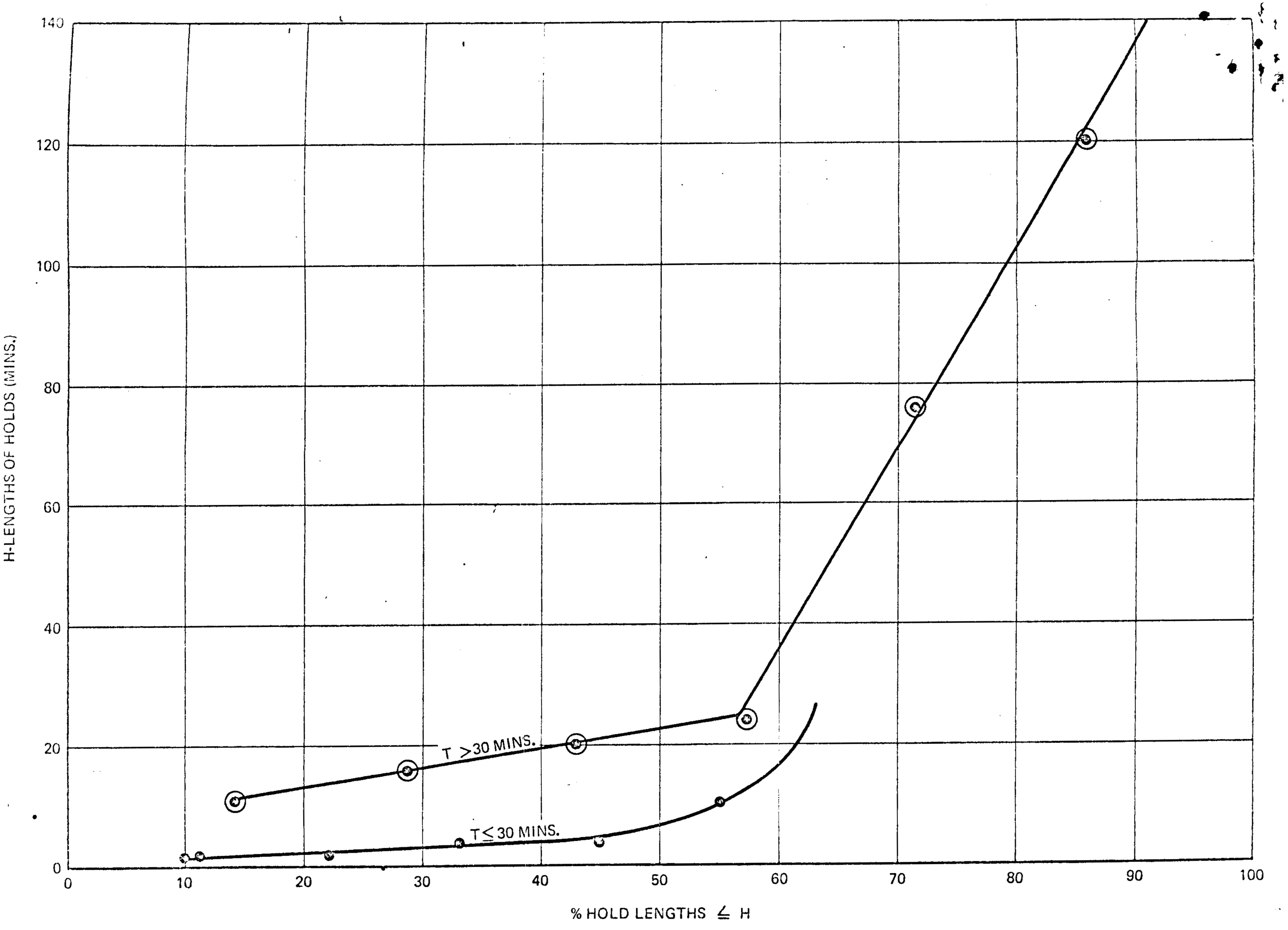

Figure 7d – LENGTHS OF HOLDS FOR LAUNCHES AND SCRUBS – GEMINI

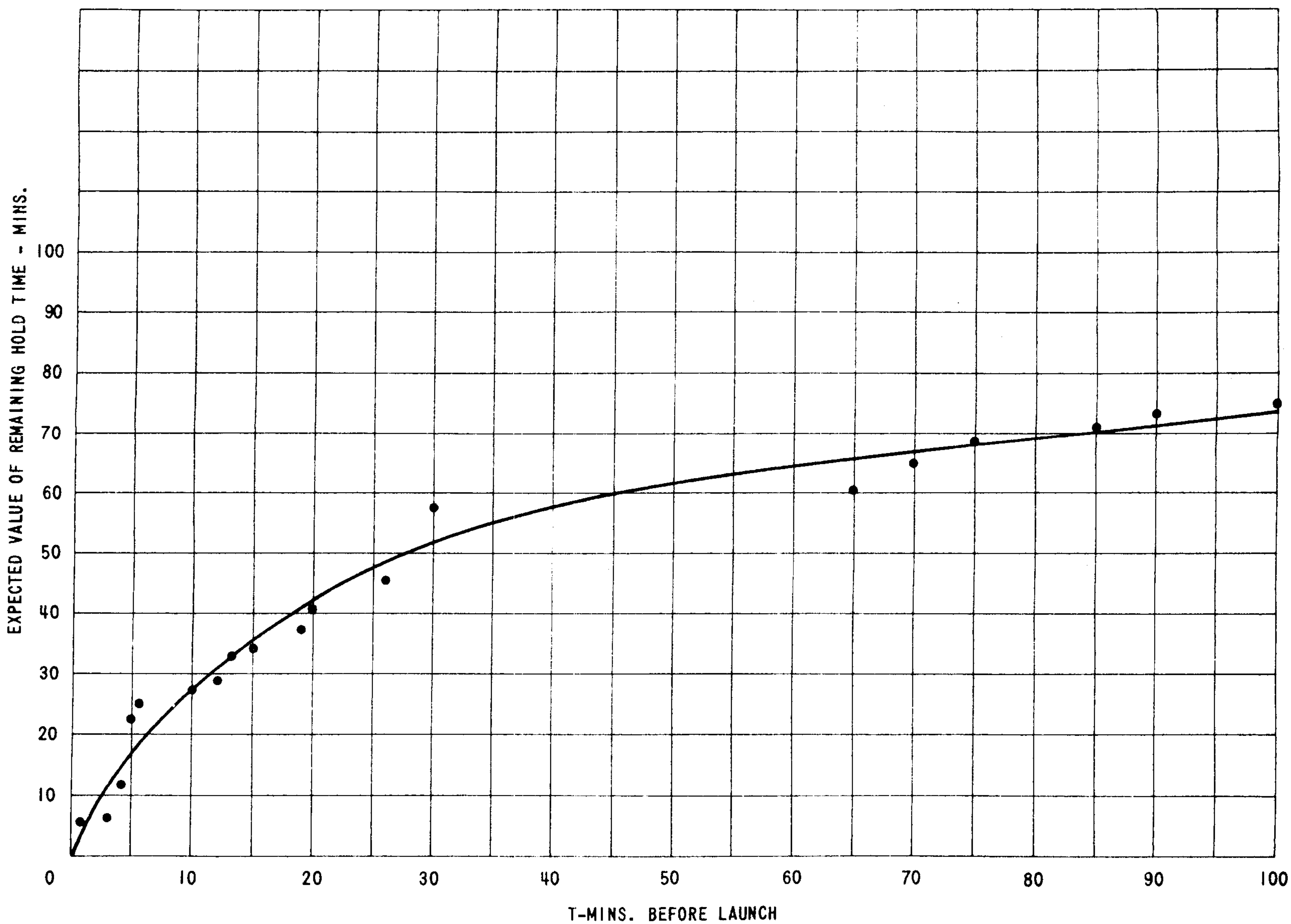

FIGURE 8 - EXPECTED VALUE OF REMAINING UNSCHEDULED HOLD TIME - SATURN I AND IB